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Mapping the collection: visualising locality data for myriapods in the Museum für Naturkunde Berlin

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Abstract

Locality data for the Myriapoda (Diplopoda, Chilopoda, Pauropoda, and Symphyla) deposited in the Museum für Naturkunde Berlin were mapped with the principal aim of highlighting areas of historical collecting activity. Data from 15,648 individual lots yielded 2,366 localities for which meaningful geographical coordinates could be determined. Most records are from Germany and Central Europe extending into the Balkans, with intensive sampling of Alpine regions. The second largest source of data is Africa, especially South Africa and the former German colonies. This is followed by Asia, particularly Indonesia, and Oceania, with notable concentrations in another former German colony in Papua New Guinea and in south-western Australia. The Americas were less heavily sampled, at least in terms of georeferenced localities. The results are placed in a historical context, with remarks on notable collectors and/or collecting trips, and some of the prospects and challenges for using these data are discussed.

Key Words

Africa, Arthropoda, Berlin, collections, locality data, Myriapoda

Introduction

Large natural history museums are important repositories of biological data (Meier and Dikow 2004; Lister and Climate Change Research Group 2011), but this information is often stored as hard copy (labels, catalogues, etc.) that cannot be easily mobilised for external users. As part of a wider project to digitise the collections of the Museum für Naturkunde Berlin, we attempted to document localities for the entire Myriapoda collection and present these data as a series of maps. For zoologists and other stakeholders, this represents a quick and easy way to visualise regions of the world that have been extensively sampled and to assess the main geographical focal areas covered by our collections. This may be useful for people planning to compile regional or national faunal lists, by indicating those countries for which data are available, as well as for taxonomists undertaking revisions, ecologists, and researchers studying particular faunas and/or distributions. It is also of cultural–historical interest for showing where collectors associated with the museum were especially active. Since early collectors were often not conducting taxon-specific sampling but simply collecting generally for the museum, our data may also represent a reasonable proxy for terrestrial invertebrates in the museum in general.

Numerous studies have used museum data to map parts of their collections. These may involve a single museum mapping part of its collection, such as Lohonya et al. (2020) for Chinese plants. Other studies have combined data from several museums, either to examine a broad group in a particular region of the world, such as Peterson and Gordillo-Martínez (2002) for Mexican birds, or to map a more specific group, such as galliform birds in a global context (Boakes et al. 2010). To our knowledge, large-scale mapping of myriapod localities based on an individual museum's data has not been carried out previously, but distribution maps for the František Miller collection of Czech and Slovak millipedes held in the Prague museum were published by Kocourek and Dolejš

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(2016). We should also mention the atlases published by Kime and Enghoff (2017, 2021) for European species of julid and chordeumatid millipedes, respectively, and Lee and Harding's (2006) atlas of British and Irish millipedes. Data from German localities – drawing in part on reference material in the Berlin museum – have also contributed to the Edaphobase project (Burkhardt et al. 2014) of the Global Biodiversity Information Facility (GBIF), from which distribution maps can be exported.

Here, our principal aim was to broadly map where the bulk of the myriapod material in the Museum für Naturkunde Berlin has come from in order to better understand the museum's potential for documenting distribution patterns in an important and diverse group of arthropods primarily associated with soil ecosystems. We also aim to place these results in a historical context by adding notes on some of the principal collectors and/or collecting expeditions.

Methods

The raw data consist of 15,648 catalogue entries, or 'lots', which were initially transcribed into a spreadsheet in their original (verbatim) form. These catalogue entries are based in turn on the specimen labels. Apart from a few misspellings or misinterpretations, we could not detect any significant loss of information between the label data and their associated catalogue entries. This reflects the careful work of previous curatorial staff, especially Manfred Moritz (curator from 1967–1996) and his assistant Sophie-Charlotte Fischer (active ca. 1973–1990), who prepared much of the written data that facilitated the present project. Locality information was updated, as far as possible, to modern usage using GeoNames (https://www.geonames.org) as the primary reference. Many places in Central Europe and the Baltic region have historical German names that were in common usage when much of the material was collected in the late 19th and early 20th centuries, and, where possible, these were corrected to their modern equivalents accordingly.

Two major contributors were the German myriapodologists Karl Verhoeff, active from 1890 to 1945 (plus some posthumous papers), and Otto Schubart, who was active in Germany/Europe from 1923 until emigrating to Brazil in 1934. Some of Verhoeff's type localities could be refined by consulting the original species descriptions in the literature, which sometimes contained more information than that written on the labels. However, a particular problem with Verhoeff was his tendency to create type series from specimens collected at more than one locality and then to label the material deposited in the museum only with the broad area from which it was obtained, e.g. "Sudtirol", "Riviera", "Siebenbürgen", etc. In such cases, we were unable to determine which objects were obtained from individual collecting sites. Some of Schubart's publications also included more information than that given on the labels. In addition, a number of Schubart's localities could be clarified based on unpublished notes kindly provided by Norman Lindner.

Once a locality name had been identified with confidence, the latitude and longitude were added, again using GeoNames as the primary source of data. For some of the more obscure places, Wikipedia (https://en.wikipedia.org/wiki/Main_Page) and other online resources, such as speleological websites for caves (e.g. https://www.showcaves.com/english/index.html), were used to provide more accurate point data. In a few cases, we had to estimate the approximate position of the locality ourselves. Examples include the former research station of "Chinchoxo" in West Africa, which has long been abandoned and is indicated only on older maps, or the Ralum station in Papua New Guinea, which had to be localised based on coordinates for an associated German colonial weather station. These raw data are available from the authors upon request and will eventually be exported into the museum's collection database. Distribution maps (Figs 1–8) were created using SimpleMappr (Shorthouse 2010) based on the coordinates as point data. Within the underlying spreadsheet, uncertainties were estimated using the point-radius method (Wieczorek et al. 2004) via the georeferencing calculator of Wieczorek and Wieczorek (2021).

Of the 15,648 entries, 652 (ca. 4%) have no locality data at all, and five were woodlice (Crustacea: Isopoda) mistakenly registered as millipedes. For the remaining localities, we excluded those for which the verbatim information could not be matched with confidence to a modern place name. This could be due to illegible or incomplete labels, transcription errors in the catalogue, or historical place names that are no longer traceable. We also excluded records where the given name could apply to more than one locality but for which we lacked additional information to resolve which of the alternatives was correct. It is possible that some of these could be clarified through, e.g. collecting diaries, but this would require focused efforts on specific collectors and is beyond the scope of the present project. Finally, we excluded locality names that were too broad to provide meaningful coordinate data. Examples include cases where only the country or state/region is given (e.g. Germany, Bavaria, the Alps). While resources such as GeoNames offer coordinates for such units, these would represent an artificial point at the centre of a large region and are unlikely to be representative of where the material was actually collected. Exceptions were made for microstates such as San Marino or small island states such as Mauritius, which cover only a limited geographical area and were therefore considered to provide useful geographical information.

Results

With these caveats in mind, we extracted a total of 2,366 locality names for the Berlin Myriapoda collection to which we could assign latitude and longitude coordinates with

some confidence (see Suppl. material 1). The dataset consists of 1,799 localities in Europe (76% of the total count), 216 in Africa (9%), 168 in Asia (7%), 102 in Oceania (4%), 31 in North America (1%), and 47 in South America (2%). Three additional localities are oceanic islands not traditionally associated with a major continent. Results for specific regions are discussed in further detail below.

Berlin/Brandenburg

Although large natural history museums such as the Museum für Naturkunde Berlin host important international collections, their significance for documenting local faunas should not be overlooked. A total of 174 localities within the city state of Berlin and the surrounding federal state of Brandenburg could be documented (Fig. 1). Brandenburg is not heavily industrialised and offers many habitats, such as forests, fens, and lakesides, suitable for collecting diverse terrestrial arthropods. Much of this local material appears to have come from museum staff, such as the former curator Friedrich Dahl, or from other individuals associated at some stage of their careers with the Berlin museum, such as Verhoeff and Schubart. It is possible that many of these records derive from local day trips within the city or its surroundings. In detail, there is a notable concentration of localities towards the south-west of Berlin, which includes both the large Grunewald forest and the Botanical Gardens in Berlin-Dahlem. Continuing further south-west into Brandenburg, there is another concentration around Potsdam. Schubart lived here in the 1930s and appears to have collected extensively in the surrounding area. There are also several localities found north-east of Berlin corresponding to what

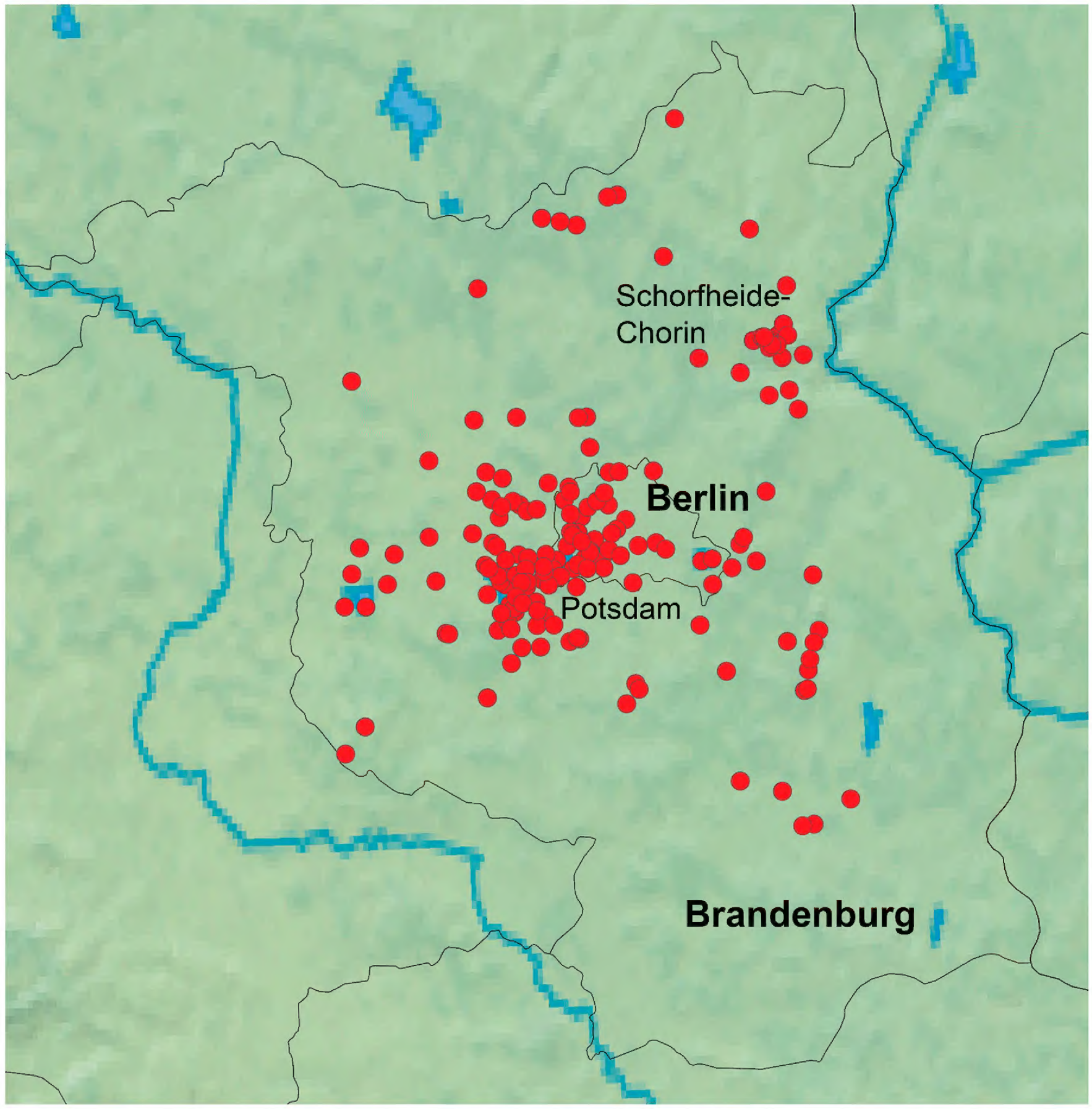

Figure 1. Localities yielding myriapods deposited in the Museum für Naturkunde Berlin that were sampled in Berlin and the surrounding federal state of Brandenburg. Note concentrations in south-eastern Berlin (largely due to the Grunewald Forest) and in the adjacent Potsdam region of Brandenburg, as well as in what is now the Schorfheide-Chorin Biosphere Reserve north-east of Berlin.

is now recognised as the Schorfheide-Chorin Biosphere Reserve. Dahl was especially active around here at the beginning of the 20th century, collecting near Chorin and in the Plagefenn/Plagesee area.

Germany and neighbouring regions

The Museum für Naturkunde Berlin is also an important depository of voucher specimens at a national level, with the potential to provide valuable data for Germany in general. A total of 793 German localities for myriapods were documented, with records from all federal states except Saarland (Fig. 2). The distribution of localities is, however, not uniform, and certain concentrations merit explanation. In addition to the many localities in Berlin/Brandenburg noted above, northern and north-eastern Germany were also sampled quite extensively, i.e. the states of Schleswig-Holstein and Mecklenburg–Western Pomerania. This is partly again thanks to Dahl, who came from Schleswig-Holstein and appears to have regularly visited his home region for collecting purposes. Schubart

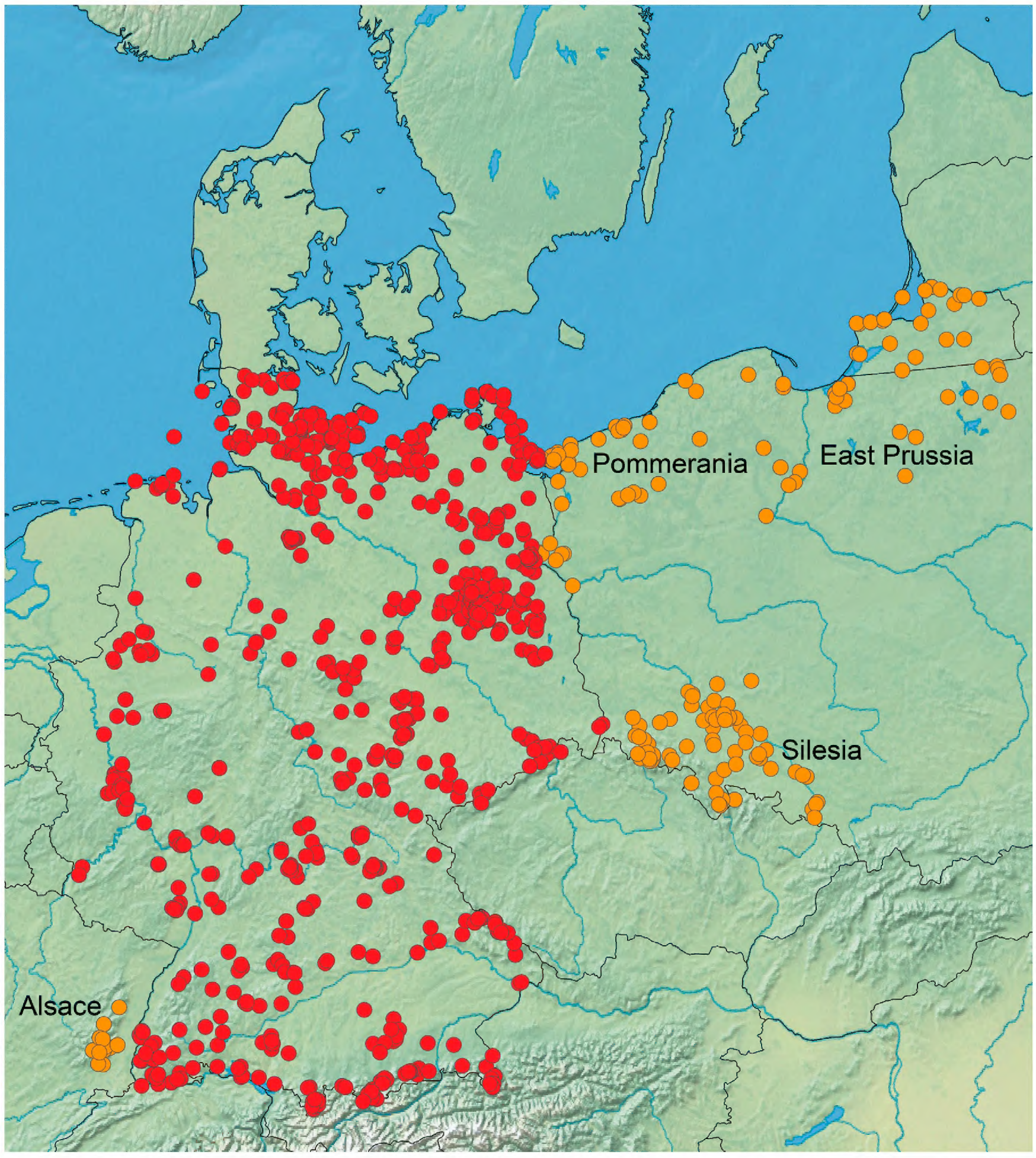

Figure 2. Localities sampled in Germany (red dots). Note the patchy distribution, with some concentrations in the north-east (i.e. Brandenburg, Mecklenburg-Vorpommern, and Schleswig-Holstein), as well as along the Alps in the south. Adding localities (orange dots) from Alsace in France and from the Silesian and Pomeranian regions of Poland up into the Kaliningrad Oblast of Russia (i.e. the former East Prussia) reveals how the Berlin museum collection reflects activity within the pre-war boundaries of Germany.

was also a native of Schleswig-Holstein and made extensive collections there, especially at the start of his career, as well as in places such as the lakes of the Mecklenburgische Seenplatte. At one stage, Schubart worked at the hydrobiological station in Plön – where he also worked on fish – which may explain why he often collected near large bodies of water (Norman Lindner, pers. comm.). Dahl also had some focal collecting regions in other parts of Germany, including Rotenfels and the "Weinstraße" in Rhineland-Palatinate, and the areas around Rothenburg ob der Tauber and Oberstdorf in Bavaria. It may be added that these are very attractive holiday destinations, and this perhaps highlights a general phenomenon that certain regions (both in Germany and abroad) have historically been collected preferentially by virtue of being popular places to visit.

For Verhoeff, the largest individual source of material, the Berlin collection somewhat reflects his career trajectory. This began with specimens from the Bonn region of North Rhine-Westphalia (where he studied), from near Berlin (where he was briefly employed), from around Dresden in Saxony and into the Erzgebirge, from around Stuttgart in Baden-Württemberg and in particular the Black Forest and the Danube Valley, and finally from around Munich in Bavaria, where he ultimately settled. Both Verhoeff and Schubart also had networks of colleagues who provided them with material from across Germany and from other countries. We suspect that these individual focal areas from the different collectors contribute towards the somewhat patchy distribution of localities (Fig. 2). Particularly noteworthy is a line of records across southern Germany in the Alpine region, which suggests this was a region of particular interest.

It should also be noted that most of the myriapod collection was assembled prior to the Second World War, with no major contributors after Verhoeff and Schubart. This means that there is no obvious "GDR effect", i.e. higher concentrations of specimens resulting from collecting restricted to the territories of the former German Democratic Republic (East Germany) or other countries under Soviet influence belonging to the Warsaw Pact. However, historically, Germany included at one stage the territories of East Prussia and Silesia in modern Poland, as well as the Alsace-Lorraine region of France. German collectors were also active in these regions in the early 20th century, and for completeness, we show these localities (here in orange) such that the museum data reflect the pre-1945 borders of Germany rather well. For example, Dahl collected in Alsace, and Schubart collected in East Prussia, i.e. northern Poland up to what is now the Kaliningrad Oblast of Russia. There is also material from numerous localities in Silesia in Poland's south-west, particularly near the valley of the River Oder, collected by Hans-Jürgen Stammer. This reiterates Berlin's potential role as an important repository for historical data about non-German faunas in Europe.

Europe

Across Europe as a whole (Fig. 3), the 1,799 recorded localities reveal that the focus is primarily on Central Europe, with a broad band of collecting localities through Germany (including its former territories; see above), Switzerland, Austria, and down into northern Italy. As noted above for Germany, the Alpine region was particularly well sampled, and Verhoeff and some of his sources of material, such as Carl Roettgen, were active here around the start of the 20th century. We can also visualise evidence of some of Verhoeff's other typical collecting areas (see also Fig. 9). These include the Italian Riviera from Genoa through to the French Riviera, the Transylvania region of Romania, and numerous places in Slovenia, Croatia, and Bosnia-Herzegovina in the Balkans. Romanian records (43 localities) were enhanced by several collectors such as Fritz Deubel, who probably identified themselves as Transylvanian Saxons, a German-speaking minority who maintained connections to Germany. Other notable sources of data shown on the map include two expeditions in the 1880s by the Berlin-based entomologist Eberhard von Oertzen focusing on Greece, and especially the Greek islands, and Otto Schubart's 1924 collections made around Lunz am See in Lower Austria. This is reflected in substantial locality counts for Italy (234), Greece (55), and Austria (83). The famous Austrian myriapodologist Carl Graf Attems also provided material from Austria, particularly Styria, and from what is now the neighbouring country of Slovenia.

Surprisingly well sampled are Estonia (23 localities) and Latvia (31 localities). Historically, these countries were home to the Baltic Germans. Similar to the Transylvanian Saxons, the Baltic Germans typically belonged to the professional or academic classes in this region and thus may have had interests in natural history. Werner Herold (see above) was from East Prussia but was especially active in the eastern Baltics (e.g. Herold 1930; Schubart 1930), and he and others provided Schubart with millipedes from this area. Fig. 3 also picks up some localities that might not be automatically expected for a German museum. For example, there are several records from Scandinavia. The Norwegian arachnologist Embrik Strand worked in Berlin for several years and brought myriapod specimens from his homeland with him. Schubart was mentored by August Thienemann, who collected in southern Sweden, and Schubart also had contacts in Denmark, such as Hans Jacob Hansen, who provided material from Bornholm and the Copenhagen area. Another focal area for Schubart was the Netherlands (23 localities), where he undertook a major collecting trip in 1926 (see also Schubart 1929; Fig. 9).

By contrast, records from Western Europe (i.e. the United Kingdom, France, Spain, and Portugal) are more sporadic. Verhoeff received some specimens from collectors in Spain and Portugal, but there were no systematic attempts to collect there. Likewise, the

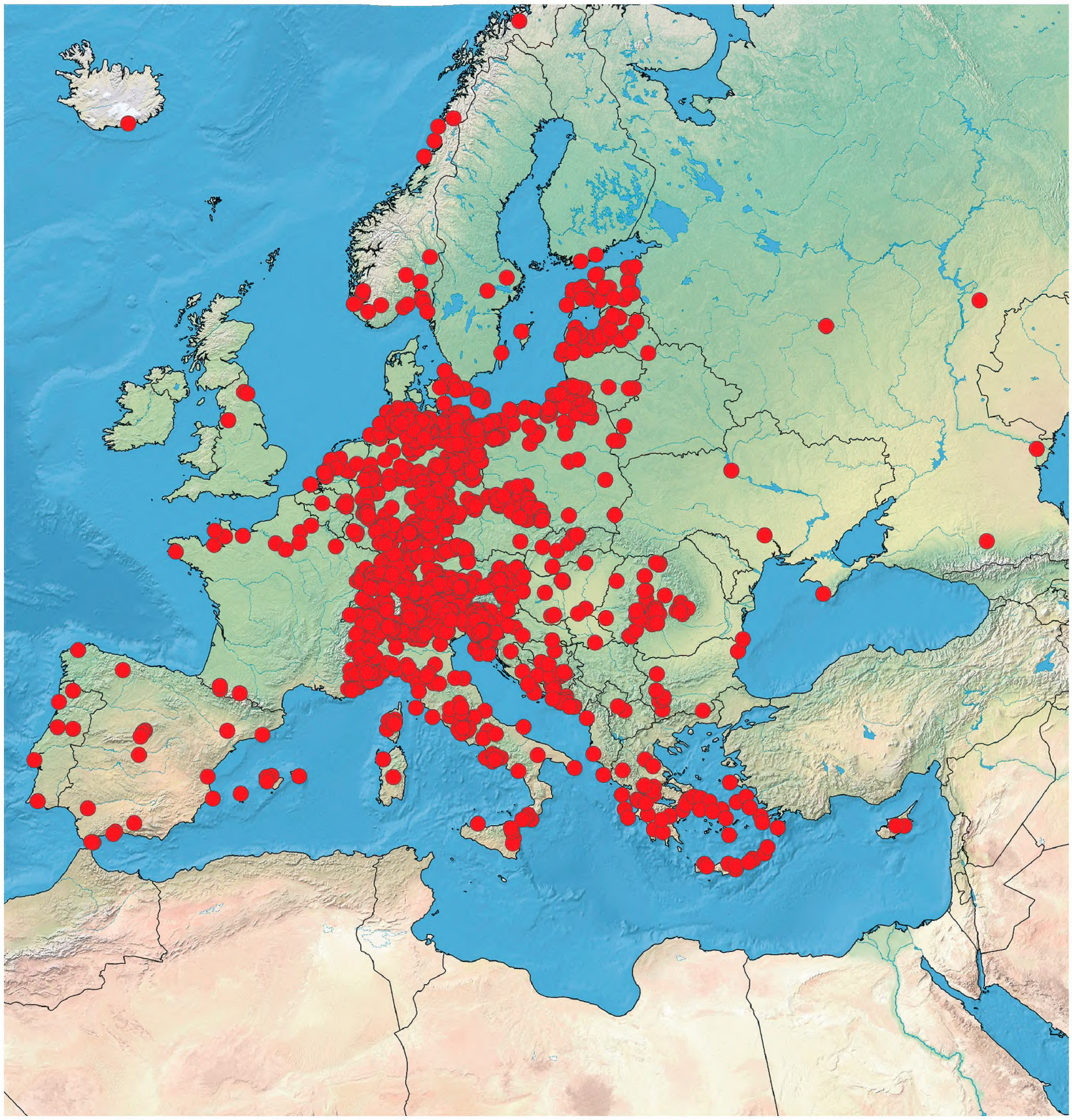

Figure 3. Localities sampled in Europe. Note the strong concentration around Central Europe, through Germany and down into the Alpine regions (Switzerland, Austria, and northern Italy). Also revealed are focal areas in Romania, the Balkans, and the Greek islands in the south, and Estonia and Latvia in the north-east. By contrast, Western and Eastern Europe have both been relatively poorly sampled.

far eastern part of Europe (e.g. Belarus, Ukraine, and the European part of Russia) is represented by only a handful of data points.

Africa

With 216 records, Africa (Fig. 4) is the second largest source of localities after Europe, underlining a strong historical connection between this continent and the Museum für Naturkunde Berlin. Nearly thirty countries on the continental mainland have been sampled to a greater or lesser degree. Apart from a few localities spread across the northern coastal regions, i.e. Morocco, Algeria, Tunisia, Libya, and Egypt, most of the material comes from sub-Saharan Africa, including both the tropics and the drier regions of countries such as Namibia, Botswana, and South Africa. In addition to the countries indicated by point data (Fig. 4), Benin was sampled under the older name of the Kingdom of Dahomey, albeit without specific localities. Several islands associated with the mainland also provided material and appear to have been popular places for collecting. These include the Azores, the Canary Islands, Madeira, and São Tomé and Príncipe on the Atlantic side, as well

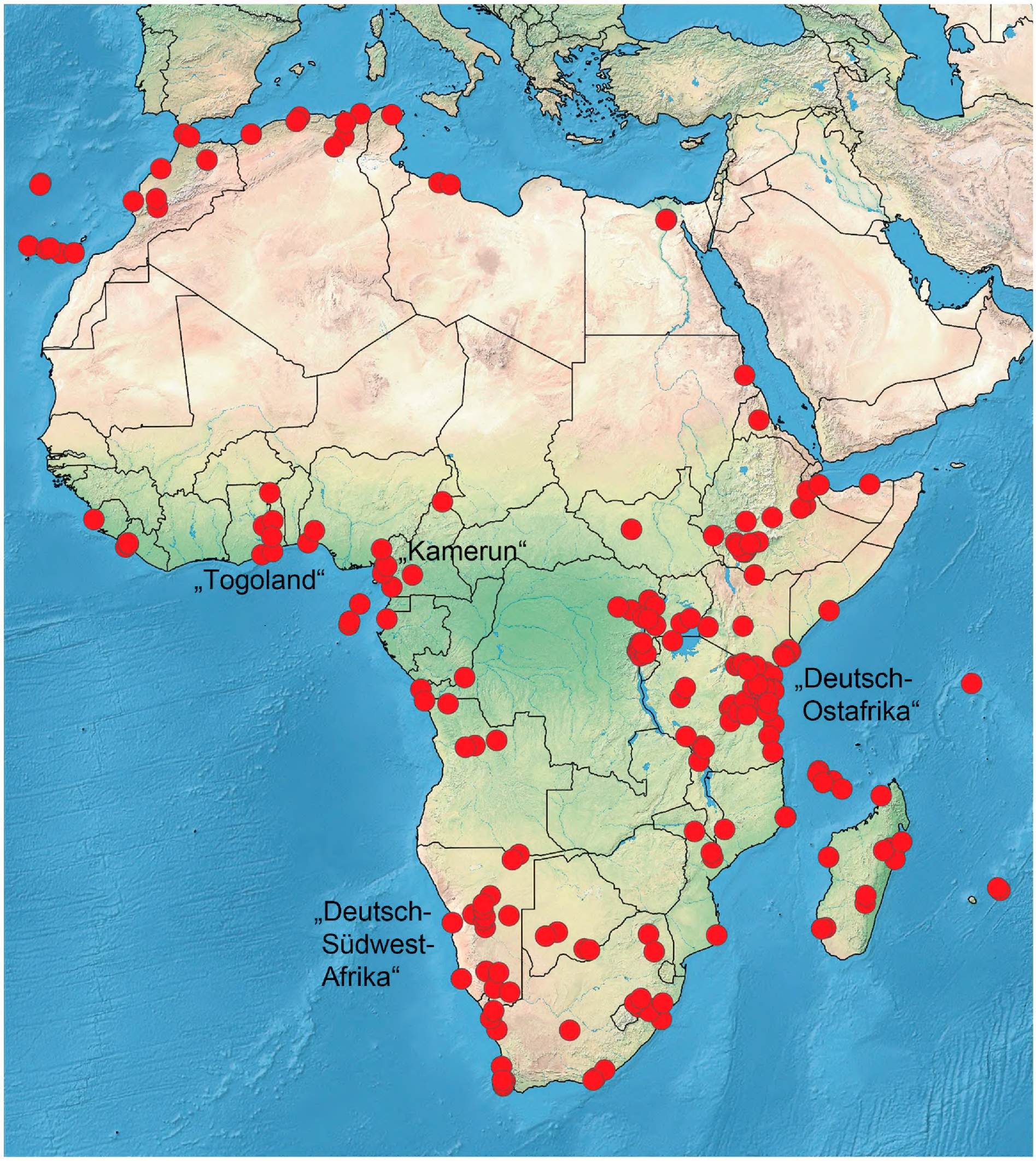

Figure 4. Localities sampled in Africa. As expected, the map shows activity in the four former German colonies of “Togoland”, “Kamerun”, “Deutsch-Südwestafrika”, and “Deutsch-Ostafrika”, but reveals additional activity in other places such as along the coast of North Africa as well as specific expeditions to Ethiopia, Angola, and Mozambique. South Africa has also been sampled quite extensively.

as Zanzibar, Madagascar, Mayotte, the Comoros, the Seychelles, and Mauritius in the Indian Ocean.

The African dataset evidently reflects Germany’s colonial past, with three localities from what is now Togo (as “Togoland”, which also included parts of modern Ghana), eight localities in Cameroon (as “Kamerun”), 16 localities in Namibia (as “Deutsch-Südwestafrika”), and 30 localities in Tanzania (as “Deutsch-Ostafrika”); the latter also included modern Rwanda, with an additional five localities, and Burundi. A number of these places were former colonial stations, the collectors often being colonial officials, military officers, or scientists dispatched to the colonies. Fig. 4 reveals notable concentrations in Togo, in coastal regions of Tanzania and the Zanzibar Archipelago, as well as further inland around Lake Victoria. Bror Yngve Sjöstedt collected around Kilimanjaro in 1905–1906. There are also several records from the region between Lake Albert and Lake Kivu in and around

the borders of Rwanda, Uganda, and the Democratic Republic of the Congo. These stem primarily from Hermann Schubotz and the 1907–1908 "Deutschen Zentralafrika-Expedition".

It should, however, be noted that there are substantial records from African countries that were not German colonies. As noted above, North Africa was collected by numerous individuals, of whom Max Quedenfeldt was among the most active in the late 19th century. Worth mentioning is Werner Peters, later a director of the Berlin museum, who collected from seven localities in Mozambique between 1842 and 1848. Also predating colonial times, the German Society for the Exploration of Equatorial Africa organised the Loango Expedition to what is now Angola. Johan Maria Hildebrandt and Alfred Voeltzkow collected extensively in Madagascar (11 localities) and the Comoros (five localities) in the 1870s, while Oscar Neumann and Carlo von Erlanger travelled through Ethiopia from 1899 to 1900, collecting from 15 localities. Finally, there was considerable activity in South Africa (27 localities), beginning with Hinrich Lichtenstein, who was the personal physician of the governor of the Cape Colony before being appointed the first director of the Berlin museum in 1810. Other Germans were active in South Africa later as, e.g. professional collectors or missionaries. Particularly notable is Leonard Schütze's 1903–1905 expedition to South Africa, Namibia, and Botswana. Verhoeff received material in the 1930s from Reginald Frederick Lawrence, mostly collected in what is now KwaZulu-Natal in South Africa – where he was director of the museum in Pietermaritzburg – and on the island of Mauritius.

Asia

The 168 Asian records (Fig. 5) include several localities in Turkey and the wider Middle East. At least some of this material appears to have been collected during archaeological investigations at sites such as Zincirli Hüyük (as

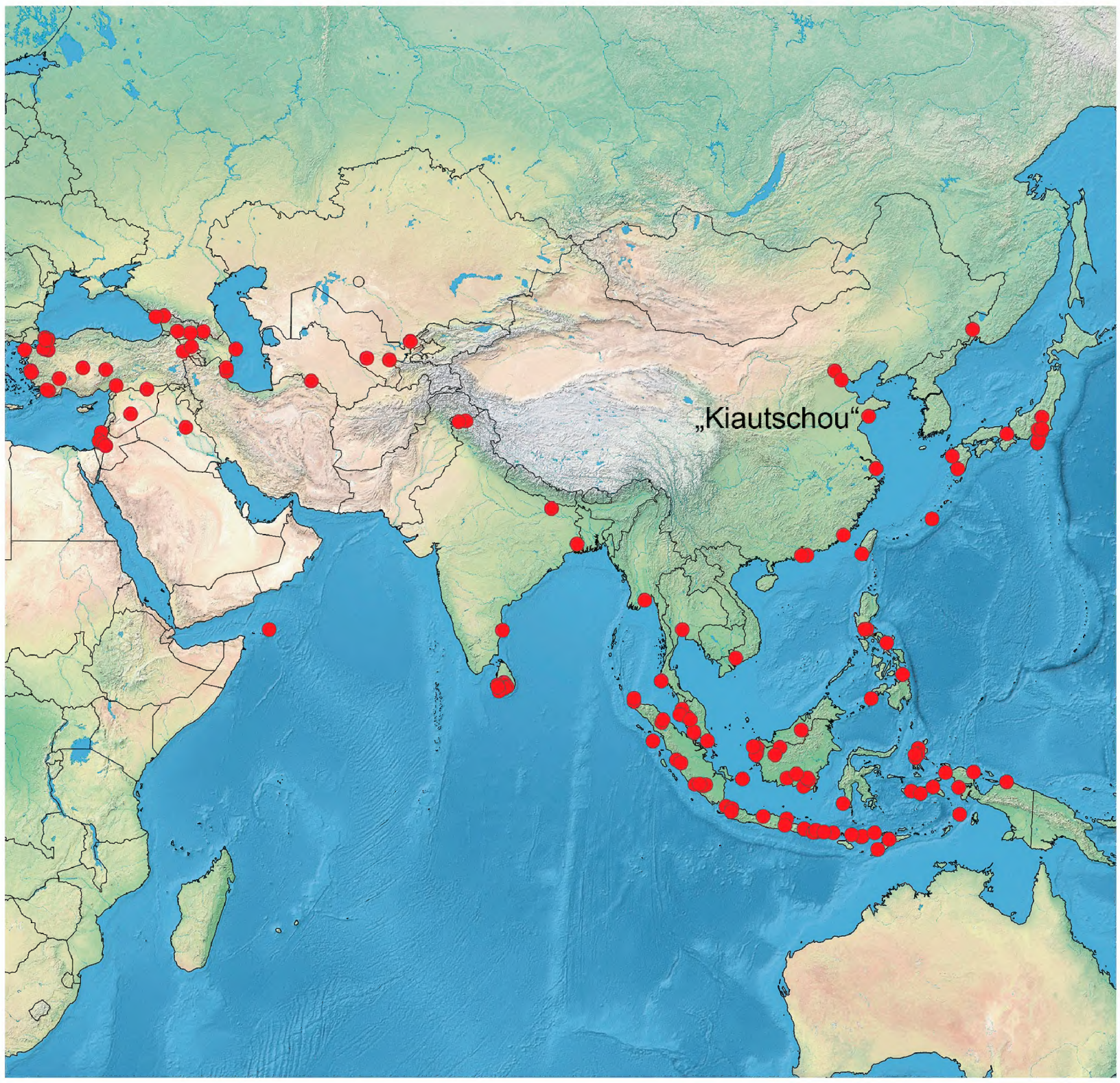

Figure 5. Localities sampled in Asia. There are a few records from Turkey, the Middle East, and the Caucasus, but most of the sampled sites come from various islands belonging to Indonesia. Note also a few coastal Chinese cities, including Qingdao, which was at one stage referred to as "Tsingtau" and belonged to the briefly existing German colony of "Kiautschou". There are also several Japanese records.

"Sandschirli") in Turkey or Palmyra and Tall Ḥalaf in Syria. There are also a few records from the Caucasus (Georgia, Armenia, Azerbaijan) and from Central Asia (Turkmenistan, Uzbekistan) through to the Tien Shan Mountains on the border with China, although the latter is too poorly documented to be included as point data on the map. In East Asia, there are a few specimens from large Chinese cities on or near the coast, such as Beijing, Shanghai, Tianjin, Xiamen, Hong Kong, and Macau. It is worth highlighting Qingdao, which, under the name "Tsingtau", was the capital of the short-lived (1898–1914) German colony of Kiautschou. Also notable are the records from Japan (17 localities). A number of these were collected by German academics such as Franz Hilgendorf and Wilhelm Dönitz, who were recruited to help modernise the country after 1868 during the so-called Meiji period. More Japanese specimens were collected in the early 20th century by Yosioki Takakuwa and came to the museum via the acquisition of Karl Verhoeff's collections. There are also records from the Korean Peninsula, but these lack specific localities. In South Asia, there are a few records from India and a notable concentration in Sri Lanka (10 localities), largely from the work of Johannes Nietner, a German plantation owner who lived for several years on the island.

Most of the Asian records come from South-east Asia (Fig. 5), in particular Indonesia, Malaysia, and the Philippines. Unfortunately, a number of these are poorly defined and refer only to large islands such as Sumatra, Java, Borneo, or New Guinea (see also below). It is also one of the regions with several historical place names that could not be matched with confidence to a modern locality, or where the same name is currently used for different places. Indonesia is the largest single source of localities, with 56 names yielding point data (Fig. 5), representing numerous sites across most of the island chain. Although Indonesia, or parts thereof, was not a German colonial possession, this region was collected quite extensively, especially by Eduard von Martens, who took part in the "Preußische Ostasienexpedition" during the 1860s and remained in the area for a year or so afterwards, and later by Bernhard Rensch as part of the 1927–1928 "Sunda Expedition".

Oceania

The 102 records from Oceania (Fig. 6) include another former colony, "Kaiser-Wilhelms-Land", which was a

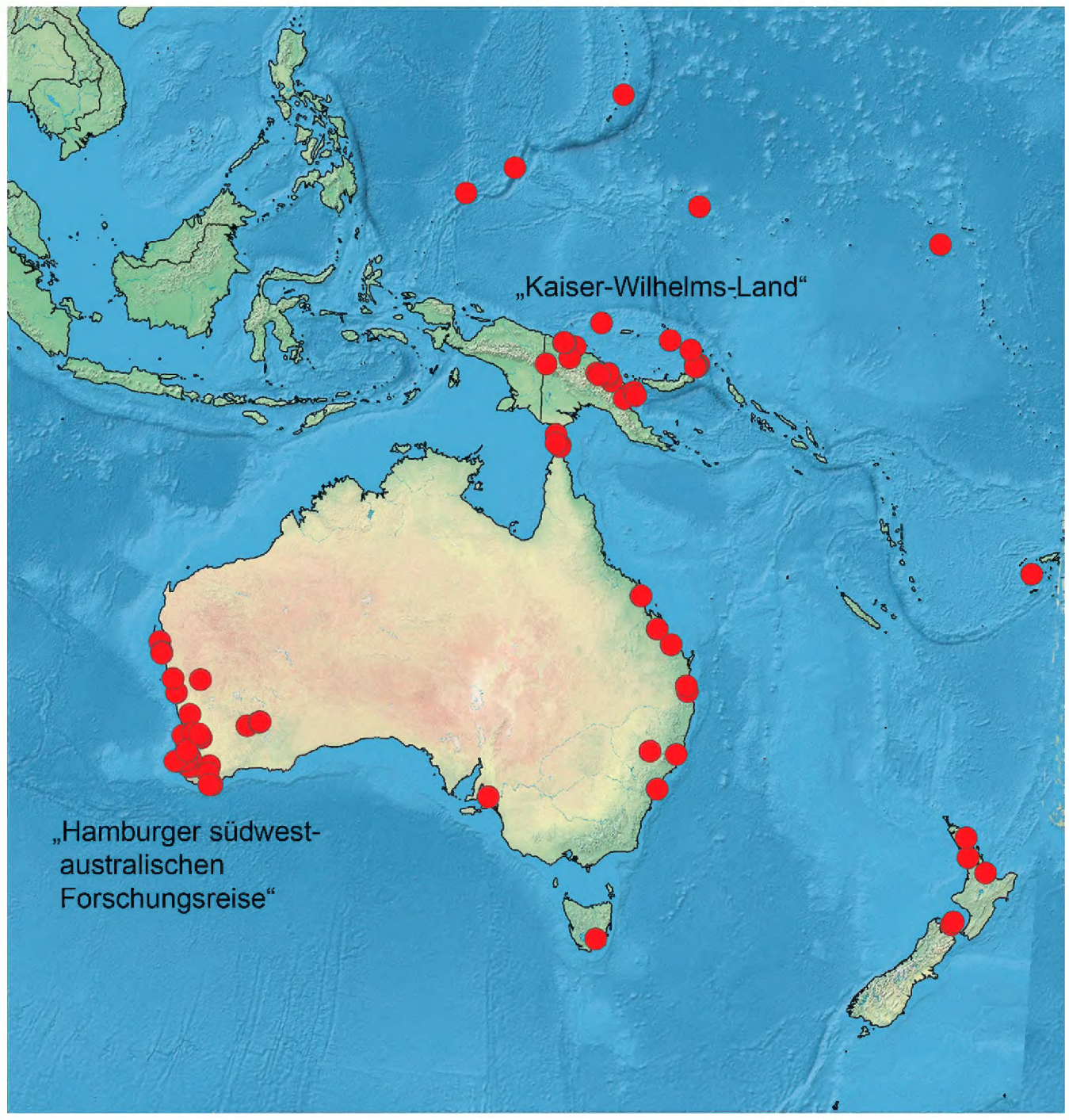

Figure 6. Localities sampled in Oceania. The former German colony of "Kaiser-Wilhelms-Land" is reflected in several localities from the northern part of Papua New Guinea. Records from Australia are largely restricted to the eastern coast and a strong concentration around Perth resulting from the "Hamburger südwest-australischen Forschungsreise". Sporadic records from New Zealand and some of the Pacific islands are also visible.

German possession from 1884 to 1920 and made up the northern part of what is now Papua New Guinea. Twenty-nine individual localities could be identified here, although several records are listed only by province. Especially active during the colonial period was Friedrich Dahl, who was based at the "Ralum" station on the Gazelle Peninsula from 1896 to 1897 (Schmitt and Glaubrecht 2013), prior to his arrival at the Berlin museum. Dahl transferred considerable amounts of material to the Berlin museum. Later, there were two major exploration trips along the Sepik River: the 1910–1911 "Deutsch-holländische Neuguinea-Grenzexpedition" and the 1912–1913 "Berliner Sepik Expedition". The localities of their material are often difficult to place precisely. While the approximate route of the expeditions is known, it is hard to georeference the finds without being able to match collecting dates to published accounts of the expeditions. In a wider context, several records are simply given as New Guinea (see also above), and it is unclear whether they belong to the modern Indonesian or Papuan part.

In Australia, some material is only broadly characterised, e.g. as Australia/New Holland, or by states (Queensland, New South Wales) or islands (Tasmania). These records were not detailed enough to include on the map. From the 60 localities with point data, there is material from, e.g. large cities such as Sydney and Adelaide. The German-born botanist Moritz Richard Schomburgk, director of the Adelaide Botanic Garden from 1865, contributed material from this region. Several localities are found in Queensland, with the naturalist Eduard Dämel noted as active in Rockhampton and Cape York in this state, as well as in Sydney in New South Wales. There is a particularly strong concentration of 42 named localities around Perth and in the south-western part of Western Australia. These stem from the 1905 "Hamburger südwest-australischen Forschungsreise" by Wilhelm Michaelsen and Robert Hartmeyer. By contrast, the interior of Australia was never collected.

Finally, a handful of records come from various Polynesian islands or island states spread across the Pacific, e.g. Fiji (Viti Levu), French Polynesia (Tahiti), the Marshall Islands (Jaluit), Micronesia (Chuuk Islands, Yap Island), the Northern Mariana Islands (Saipan), Palau, and Samoa (Apia). Several of these belonged to the 1900–1920 protectorate known as "German Samoa".

North America

North America is the least well-represented region of the world, with only 31 georeferenced localities spread across the USA, Central America, and the Caribbean (Fig. 7).

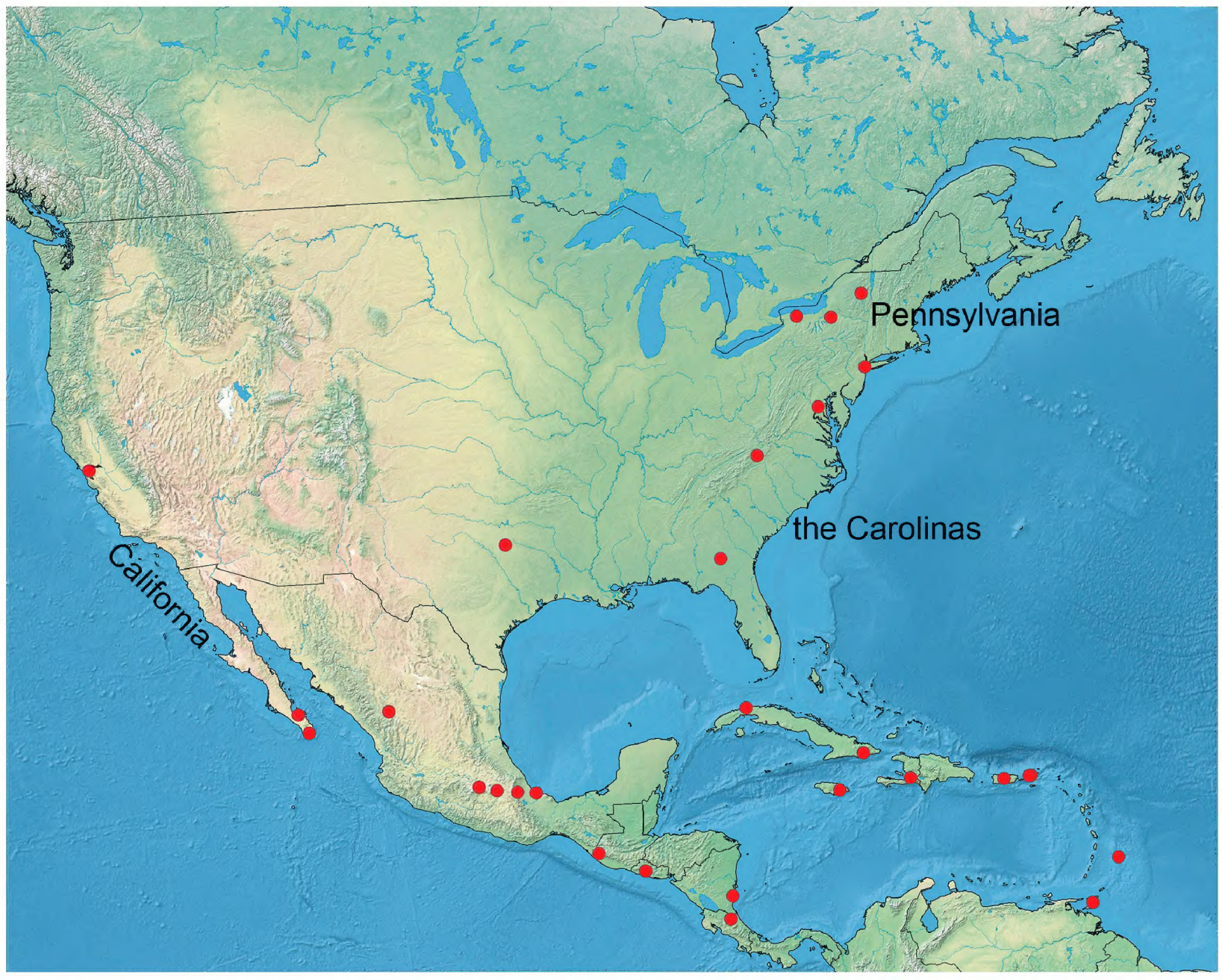

Figure 7. Localities sampled in North America. This is the least well-sampled region in terms of locality number, with only sporadic records from the USA, Central America, and the Caribbean. There are, however, numerous historical specimens from Pennsylvania and the Carolinas, as well as from "California" (probably from a time when the name also referred to a part of Mexico), but specific localities were unfortunately not recorded.

There are no records from Canada. The largest single concentration of localities is in and around New York City, but still represents only a handful of sites. A substantial source of material was Puerto Rico, with collections from the mid-19th century by Carl (Karl) Moritz and Carl Wilhelm Leopold Krug; however, precise localities on the island were not recorded. It should be added that several other notable collections from the early 19th century could not be adequately mapped, as they mention only the country and/or state of origin, e.g. Christoph Zimmermann's material from Pennsylvania and the Carolinas, or Ferdinand Deppe's specimens from Mexico. There is also material collected by Alphonse Forrer and ascribed to the Californias, but given the likely time of collection this may not refer to the modern state of California and could encompass a large part of the south-western USA and/or parts of Mexico. For Zimmermann, Deppe, and Forrer, the absence of specific localities precludes their inclusion as point data in Fig. 7. A similar problem affects material assigned to the historical region of Veragua, which today corresponds to parts of Costa Rica, Nicaragua, and Panama.

South America

Of the twelve independent countries making up South America (Fig. 8), the collection includes material from all of them except French Guiana. A handful of records from Bolivia and Suriname lack specific localities and could not be mapped. A substantial number of specimens were collected by Otto Finsch in Peru and by Moritz Richard Schomburgk in Guyana (prior to moving to Australia; see above), but again, detailed localities were not recorded. Similar to the above-mentioned Veragua problem, some older material was assigned to the historical Viceroyalty of New Granada, which covered a large part of north-eastern South America plus part of Central America. It cannot be translated meaningfully into modern point data and represents a general problem whereby older material was often assigned only to a country or region.

From the specimens yielding point data, 49 specific localities in South America could be documented. The largest single source of data in terms of raw specimen numbers is probably Brazil, although only nine localities

Figure 8. Localities sampled in South America. As with North America, sampling was again rather sporadic, albeit with some concentration in Colombia, Ecuador, Paraguay, and Chile. Many finds from countries such as Brazil are too poorly documented to translate into meaningful point data; thus, the map probably underestimates the total contribution of this region to the collections.`

could be formally mapped here (Fig. 8). Several specimens are assigned simply to Brazil or to states within Brazil such as Bahia, Pará, or Santa Catarina. For some older records, localities could perhaps be inferred. For example, Ignaz von Olfers was based in Rio de Janeiro in the early 19th century as a diplomat, but further research would be needed to assess to what extent he collected (or received material from) beyond this region. Another early collector, Friedrich Sello, has fairly well-documented collecting areas near Rio and beyond (Zischler et al. 2013), but without specific collecting dates it is difficult to match specimens to localities. Chile is also fairly well covered, with 11 localities including the Juan Fernández Islands. The principal collector in Chile was Ludwig Hermann Plate. There are small concentrations of collecting activity around Caracas in Venezuela and Asunción in Paraguay. The Venezuelan material is typically associated with Julius Gollmer and includes myriapods from, e.g. Colonia Tovar, which was founded by German immigrants. Specimens from Paraguay are largely credited to the Italian myriapodologist Fillipo Silvestri, who exchanged material with Berlin, although it is unclear whether he collected them himself. The only named locality for Colombia is Bogotá, with Alexander Lindig as the collector.

Islands

Not shown in the maps are a handful of locality records from islands that are not normally associated with particular continents but are mentioned here for completeness: the Azores and Saint Helena in the Atlantic Ocean, and the Île Saint-Paul from the French Southern and Antarctic Lands. Material from these islands was collected, in part, during stopovers of the 1903–1905 "Deutsche Südpolar-Expedition".

Discussion

Georeferenced specimen data have much potential as a scientific resource, but their acquisition and management are not without problems (Marcer et al. 2021), and there is now an extensive body of literature discussing this subject (see e.g. Murphey et al. 2004; McEachern and Niessen 2009; Nekola et al. 2019; Thorn 2022, and references therein). Much of this debate relates to the methods and accuracy of georeferencing, as well as the perennial problem of misidentified specimens contributing to erroneous species distribution maps (Sikes et al. 2016). In this context, we should stress that our primary aim here was simply to gain an overview of where our specimens come from, clarify some historical place names, and provide accurate data on the provenance of taxa, and to present this information visually in a format that is easy for collection users to interpret. This is not detailed distributional or ecological data, and for these purposes the raw data would almost certainly require further analysis (cf. Ponder et al. 2001; Graham et al. 2004). Indeed, one of the motivations for the present study was to identify areas with high levels of collecting activity. Based on these, we could encourage researchers with expertise in these geographical areas to work with the collections, check specimen identifications, and thus hopefully improve the overall quality of the information.

The point data generated for individual species also have the potential to contribute towards distribution maps and information in online resources such as the scratchpad-based Myriatrix (http://myriatrix.myspecies.info) and the Millibase (https://www.millibase.org/) and Chilobase (https://chilobase.biologia.unipd.it/) websites, which summarise taxonomic information for myriapods. Interestingly, several areas that were sampled fairly intensively correspond to regions now classified as biodiversity hotspots sensu Myers et al. (2000). In Europe, these include the Mediterranean Basin; in Africa, Tanzania, Madagascar, and the Cape region of South Africa; in Asia, the Caucasus, Sri Lanka, and the Sundaland–Wallacea–Philippines complex; in Oceania, south-western Australia and, to an extent, Polynesia; and perhaps in South America, parts of the tropical Andes, Brazil's Atlantic forests, and parts of Chile. Our data are also of historical interest and allow us to map contributions from individual collectors. As an example (Fig. 9), we show the relative contributions and principal collecting areas in Central Europe for our five most productive sources of material: Karl Verhoeff, Otto Schubart, Friedrich Dahl, Hans-Jürgen Stammer, and Werner Herold.

Notwithstanding these positive aspects, the collection data present some challenges. With the exception of some localities that could be matched to remarkably detailed diaries prepared by Friedrich Dahl for his German specimens or to specific published descriptions of localities by Otto Schubart, much of the historical metadata is rather crude and offers little in terms of precise collecting sites or habitat information. This is a general problem with older collections, where the name of the closest town or geographical feature was presumably used as a proxy for labelling purposes. This is to some extent ameliorated by the addition of uncertainty radii sensu Wieczorek and Wieczorek (2021), although we should be aware that modern towns and cities – whose size forms the basis of these estimates – may be somewhat larger than when the material was collected in the 19th or early 20th century. It was also apparent that localities closer to Berlin and Germany tend to have more accurate data. Particularly among the older catalogue entries, 'exotic' material was often simply assigned to the country of origin (China, Japan, Brazil, etc.) or to a broad region thereof. Another problem is that the maps presented here record places but do not indicate how much material each locality yielded. For example, a single *Lithobius* sp. centipede from Iceland is represented as one point on the map. One hundred and sixty-six lots, all from Dahme in northern Germany,

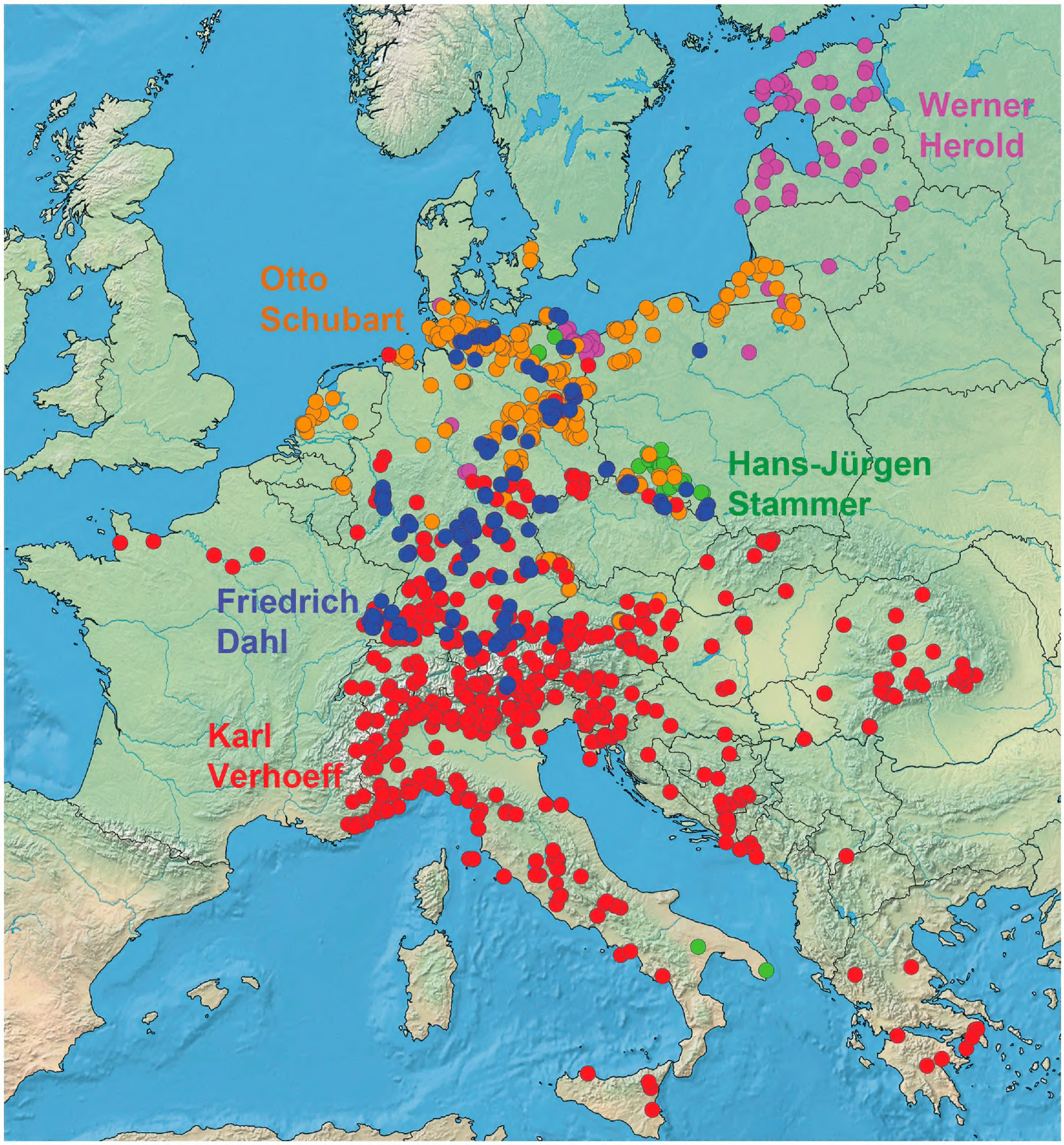

Figure 9. As an example of how to apply these data, localities in Central Europe sampled by our five most productive myriapod collectors are shown: Karl Verhoeff (red dots), Otto Schubart (orange), Friedrich Dahl (blue), Hans-Jürgen Stammer (green), and Werner Herold (pink). The principal focal areas of each of these scientists can be easily visualised based on the Berlin Museum data.

are also expressed as a single point, although they represent a much richer source of information. Future refinements could address ways of visualising collecting intensity in addition to geographical locality.

Finally, we would like to reiterate that mapping, especially of older collection data, is not a trivial undertaking (see also Hill et al. 2009) and demands an appreciation of geography and history beyond the usual biological training of curatorial staff in natural history museums. Our experience suggests that while some localities can be pinpointed fairly easily, others require considerable effort, especially if they are in regions that have undergone political changes across the 19th and 20th centuries with extensive renaming of geographical features. Online resources are often extremely useful in this regard; for example, GeoNames lists alternative names and spellings. Historical or genealogical websites such as https://meta.genealogy.net/ also proved helpful for tracking down central and eastern European localities under their earlier German names. However, some of our localities remained frustratingly elusive, usually because the inscription on the label could not be matched to a modern

place name, or because the same name could apply to more than one locality. We encountered several names for small settlements that could represent a place in Germany but were also used historically for places in what is now Poland. For example, there are several Lunows, including one in Brandenburg but also Łunowo in West Pomerania, both of which fall within known areas of collecting activity. Further coordination with the museum's historical archives may provide the context needed to decide between alternatives. In any case, curation is inevitably an ongoing process, and our hope is that the data we have prepared here for the Myriapoda in Berlin can form a solid baseline for future studies of these animals' global distribution.

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Supplementary material 1

Locality data

Authors: Jason A. Dunlop, Anja Friederichs
Data type: xlsx
Explanation note: Excel table showing the georeferenced localities for the Myriapoda collection of the Museum für Naturkunde Berlin, cross-referenced to the principal known collectors.
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Link: https://doi.org/10.3897/zse.102.167065.suppl1